Note on the integration of the ILD detector

C. Clerc, M. Joré

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Laboratoire de l'Accélérateur Linéaire

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Catherine Clerc

LLR, Ecole Polytechnique, CNRS/IN2P3, Palaiseau, France

Matthieu Joré

LAL, Univ Paris-Sud, CNRS/IN2P3, Orsay, France

U.M.R
de
l'Université Paris-Sud

Institut National de
Physique Nucléaire et de
Physique des Particules du CNRS

LAL ~ Bât. 200 ~ B.P. 34 ~ 91898 Orsay Cedex ~ France

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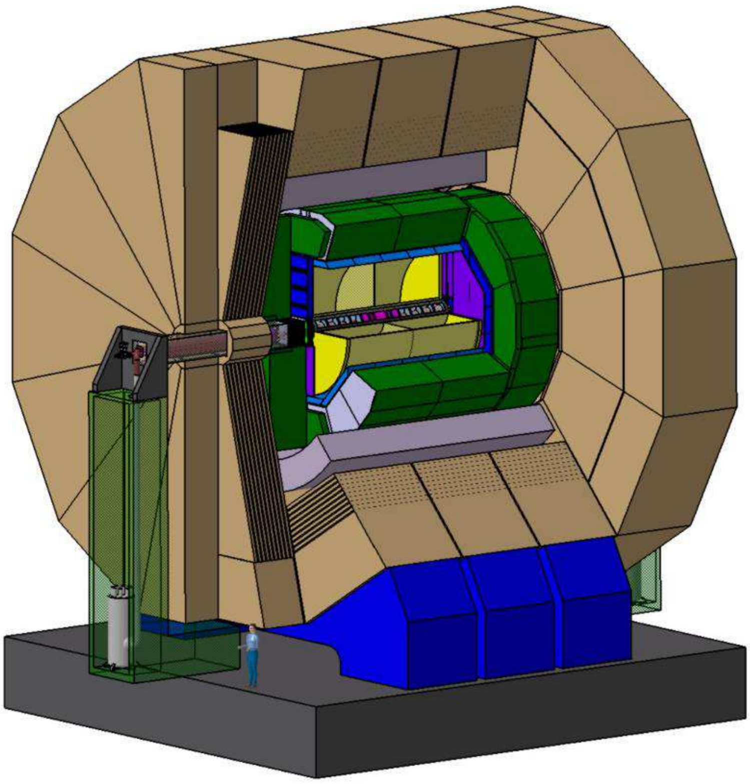


This note summarises part of the studies done on the detector integration and gives details on the actual status of the overall integration of ILD. This document provides supplementary informations to the Letter of Intent. Despite some missing parts, we identify baseline principles which still need R&D and close discussions with the different groups involved in the ILD concept.

This document describes the assembly of the sub-detectors (according to their differences), gives a proposal for the cabling scheme and the possible opening scenarios.

- Table of content -

1. Overview of the ILD detector

The picture below represents the present design of ILD. The overall dimensions are about 15m diameter per 13m long. The total weight is more than 15000tons.

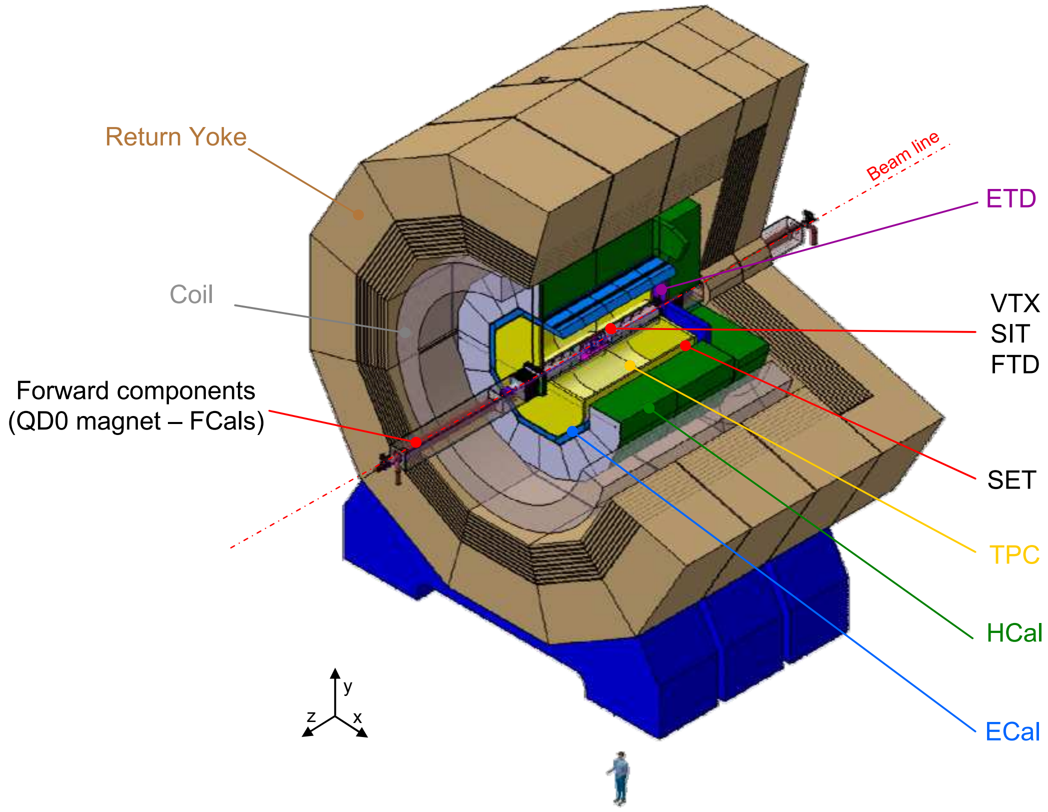


FIGURE 1.1 3D overview of ILD detector

The z axis, symmetry axis of the detector, is defined as the bisector of the two beam directions in the electron direction. The x axis is the second bisector of the beams. The y axis completes the direct axis system, it is vertical[1].

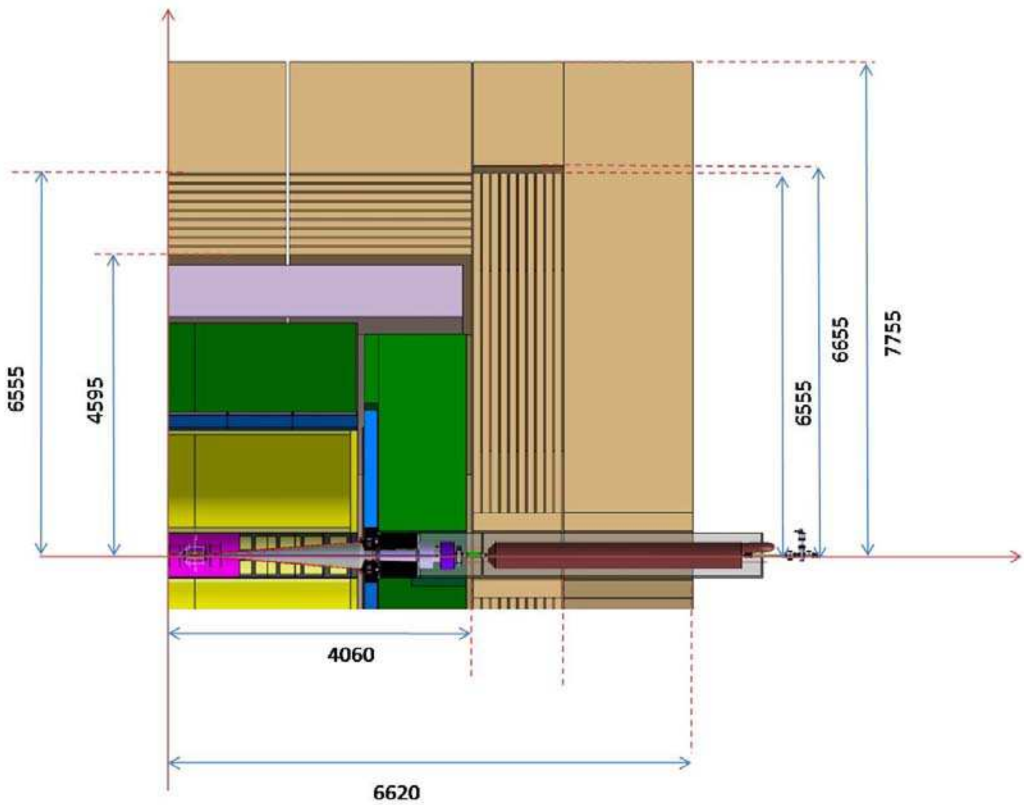


FIGURE 1.2 quadrant view of ILD detector

2. Integration of sub-detectors

All the studies performed were driven by the following constraints:

- Easiest maintenance scenario.
- Detector as compact as possible
- Limitation of the weight of the ensembles to be lowered down in the pit after pre-assembly on surface depending of the gantry crane possibilities

2.1. Barrel and yoke

According to the introduced constraints, we decided to follow the integration concept used in CMS. The principles are the following:

- Segmentation of the yoke barrel into three pieces.
- Support of the coil and its cryostat by the central yoke ring.
- Barrel calorimeters and TPC are supported by the coil cryostat.

With this design the dimensions of the muon chambers, embedded in the yoke, and the yoke itself stay reasonable and allow for an easy maintenance scenario. This of course has an impact on the cabling scheme which will be detailed in a next chapter.
The mechanical construction of the yoke would not be detailed in this note.

2.1.1. Hadronic Calorimeter (HCal)

The HCAl barrel integration is slightly different for the two different options (AnalogHCal or SemiDigitalHCal):

- The AHCal option barrel is divided into two wheels of 16 modules each. They will be inserted on rails in the cryostat by each side of the detector.
- The SDHCal option will be segmented into 5 wheels of 8 modules each, and pre-assembled as one full barrel before insertion in the cryostat using rails as guides and supports.

Those rails are integrated into the coil cryostat inner skin at a radial location close to 3-9 o'clock. However, their final position has to be optimised in order to reduce the deformation of the Hcal.

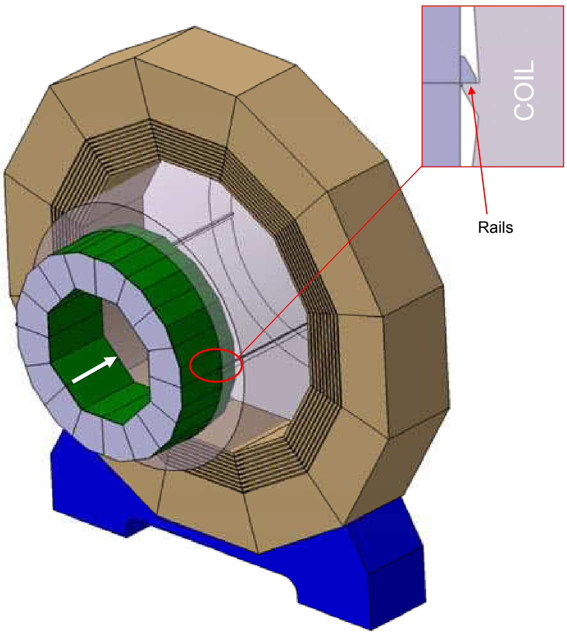


FIGURE 2.1.1.1 Mounting of the HCal barrel

2.1.2. Electromagnetic Calorimeter (ECal)

There are two options under study for the ILD ECal:

- Silicon detectors & Tungsten as absorber (Si/W)
- Scintillator tiles & Tungsten(Sc/W)

Both are planning to use carbon fiber for holding structure.

The ECal will consist in five rings of eight modules each. The stave assembly will be done before installation in the detector. Then they will be slit on rails bolted on the HCal inner face. By now, the number of rails is 3 or 2 per stave and may evolve.

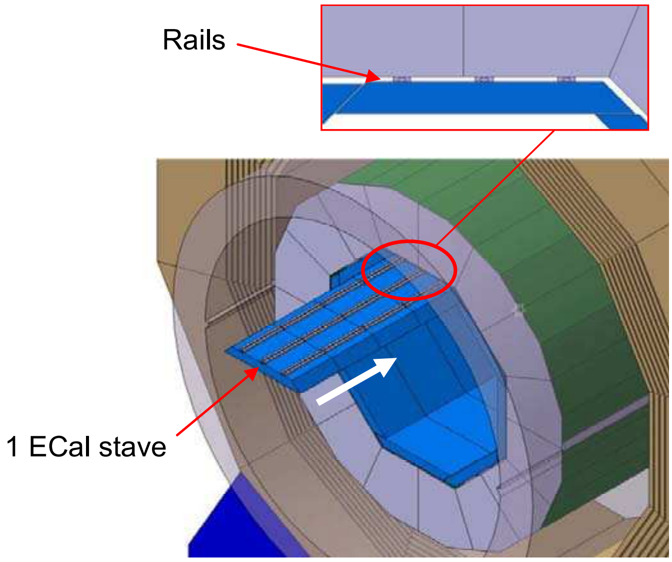


FIGURE 2.1.2.1 ECal insertion

2.1.3. Time Projection Chamber (TPC)

The TPC will be suspended from either coil cryostat or Hcal front face by tie rods in order to have a tunable, stable and isostatic supporting method. As the best mechanical behavior (vibration and thermal) is provided by smaller rods, the fixation on HCal face would be preferred. On the other hand we may need some alignment means which could more easily sit close to the coil.

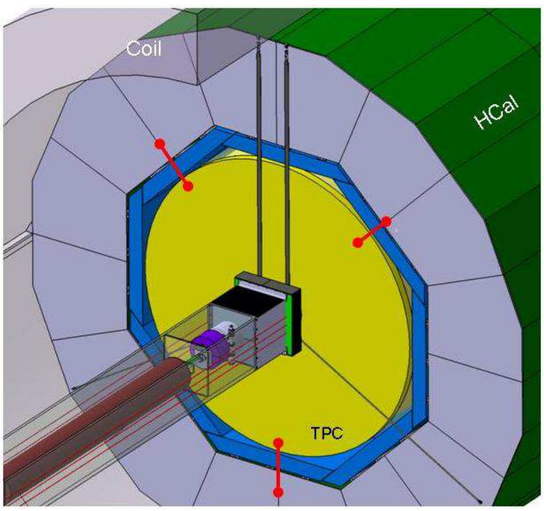


FIGURE 2.1.3.1 Supporting method of the TPC

2.2. Endcaps

As for CMS, the yoke Endcap will support the Endcap calorimeters and the ETD silicon disks.

The segmentation of the yoke Endcap is still under study, but the last design is the following:

- Front ring with 10 embedded muon chambers
- A back part, which may be split in 2 in x direction in order to maximise the access when on beam (see next chapter).

An additional magnetic plate is placed in front of the yoke endcap to improve the field homogeneity in the TPC. It is called FSP (Field Shaping plate)

The connection between yoke and Hcal Endcap (non magnetic) has to avoid bending of the calorimeters when switching on the magnet.

The ECal Endcap will be composed of 4 quarters made of 3 pieces. Today, its precise segmentation still depends on the technical feasibility of long modules (ab. 2m). Each module will be slit along rails on the HCal front face.

The ETD (Endcap Tracking Detector) is fastened on the Ecal endcap front face. The mechanical design is under study by the SiLC collaboration[2].

The integration of the MONALISA device[3], a proposed system for monitoring the QD0s' position, will be studied in a next step.

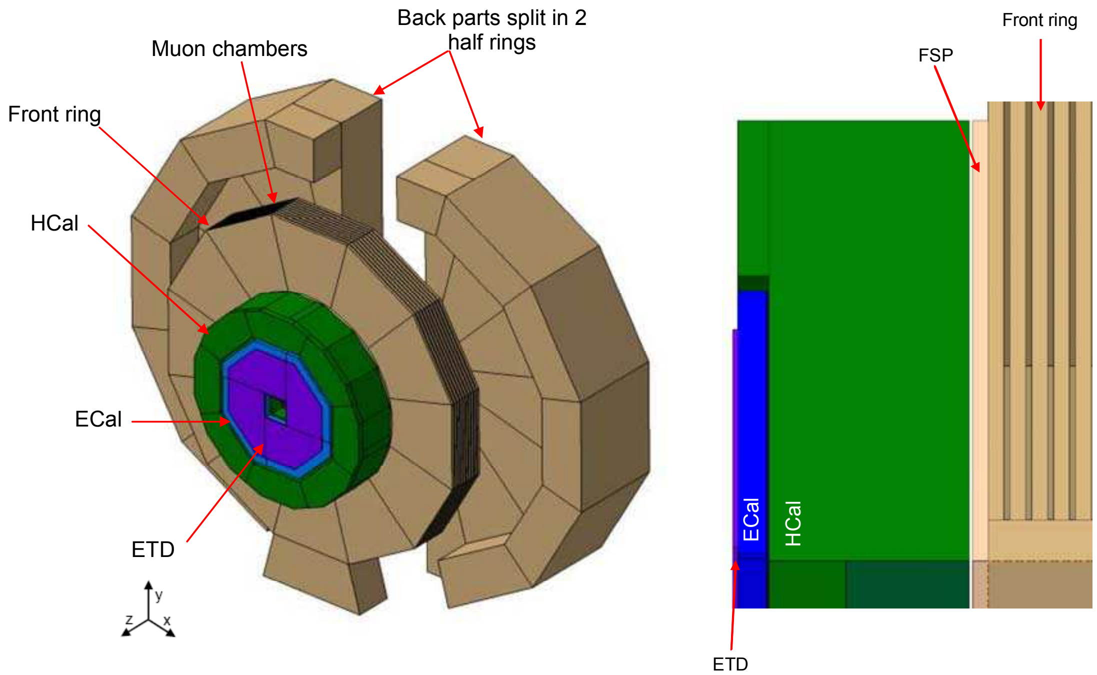


FIGURE 2.2.1 3D view and section in yz plane of one design proposal for the ILD Endcap

2.3. Inner detectors

The principle of this region is to assemble all those components in one rigid structure, inserted in the TPC and hanged on both sides from the TPC endplates. Then, the elements of the actual design are the following (see figure 2.3.1):

- The beam pipe is conical to minimise its incidence on luminosity measurements
- Vertex detector is clamped on the beam pipe
- The Inner Support Structure which supports all the silicon disks and sustains the beam pipe via cables (in blue on figure below) is hanged both sides from the TPC Endplates. Its alignment has to be tunable with respect to the beam axis (defined by a line from each QF1)
- Bellows on both side to insulate the inner beam pipe from the 2 forward assemblies (see figure 2.4.3.5)

This assembly has to fulfil several constraints:

- Precision on Vertex and Silicon disks positions
- Adjustment needed for alignment to the beam axis (<1mm)
- Low material budget.
- Fit with the beam pipe design [4]

The Inner Support Structure becomes the heart of the inner region and can be slid into the TPC using a special tooling. The total weight is estimated to be less than 50Kg and then seems compatible with the TPC Endplates design (TPC weight is about 4 tons).

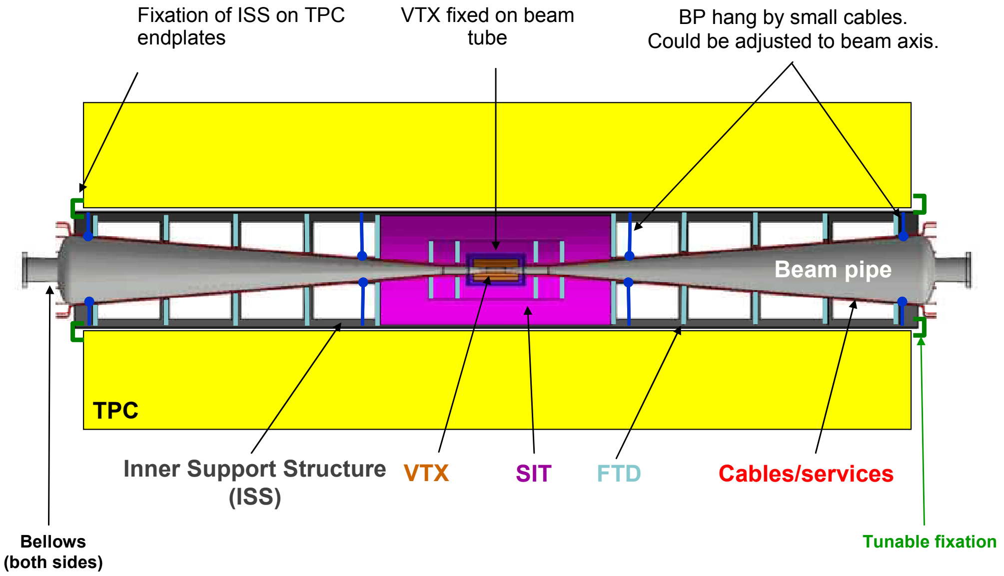


FIGURE 2.3.1 Inner detectors assembly

2.4. Forward region

2.4.1. Description

The forward region is composed by:

- the final focus magnet (named QD0), which needs high stability for providing the required luminosity [5]
- the machine components (BPM, Kicker, pumps, valves, gauges)
- all the Forward Calorimeters (LumiCal, ECal ring, LHCal, BeamCal) for a total weight of about 4 tons (see FIGURE 2.4.1).

An isolating valve is positioned behind the Beamcal to keep the final focus magnet cold during maintenance.

The connection between forward and inner beam pipe is made by a flange located between LumiCal and LHCal. That way, it stays accessible without dismounting the LHCal and doesn't compromise the luminosity measurement.

In order to reach the required vacuum pressure (<10nTorr), a pump is integrated between LHCal and BeamCal.

The proposal is to integrate them in a single structure, a square support tube.

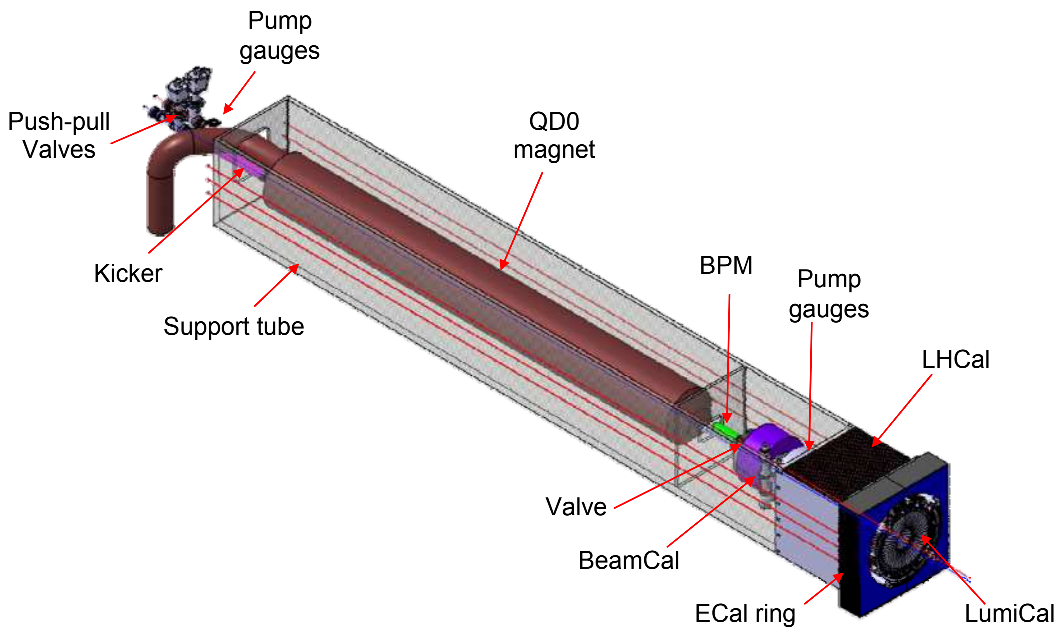


FIGURE 2.4.1.1 Forward region components

2.4.2. Support tube

The support tube will be a square structure of stainless steel plates (30 mm thick), partly open on its top. Its vibration behavior has to be studied and to be optimised, but the first results indicate that the IR interface document requirements are fulfilled [6].

It will be aligned in a millimeter range to the beam axis .The fine adjustment of the QD0 magnet will be obtained by movers integrated between QD0 and the support tube. The design of this component is under the BDS group responsibility.

For stability reasons, we chose to sustain it on each side:

- Outside the detector using a pillar
- Inside the detector with two vertical tension rods attached on the coil cryostat.

Those two vertical rods must pass in the 10cm gap between barrel and Endcap. They will be made of CFRP (low material budget, high mechanical performance) and their length is adjustable. The link between tie rods and the support tube is performed by 2 Titanium arms (60mm diam.) integrated between the LumiCal and the ECal ring. Two small rods, tilted from x axis, are added to improve the stability of the assembly.

The pillar, fixed to the platform, will integrate all the QD0 services (cryolines, cold box, cables…), the pumping system of the beam line and also the cables and services exiting from the detector. The advantage of this design is to have a support solution totally independent from the machine allowing for a quick push-pull.

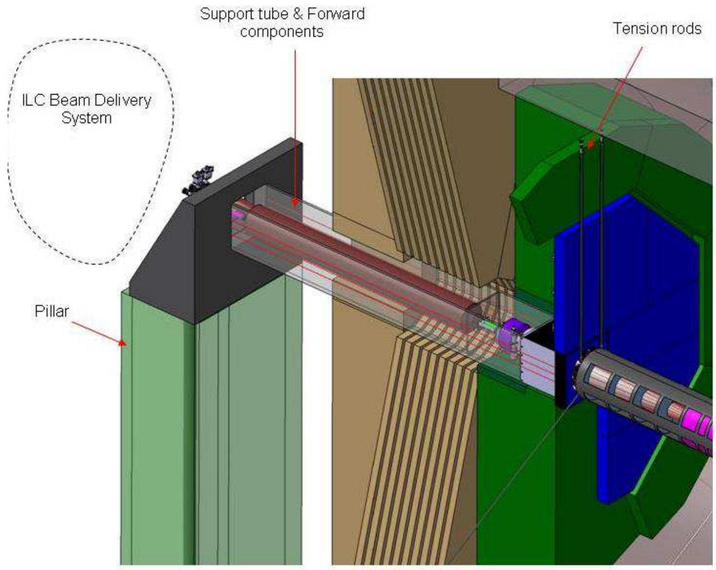
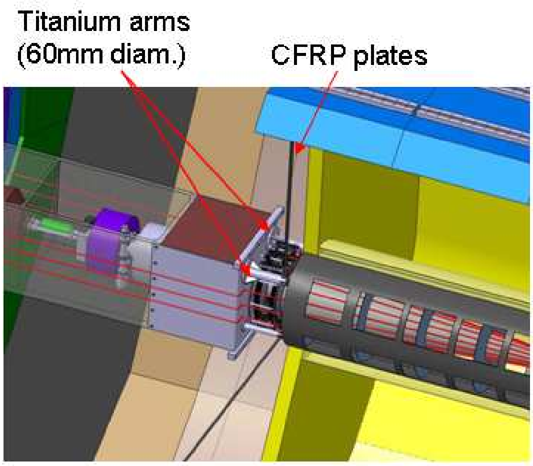


FIGURE 2.4.2.1 Support tube



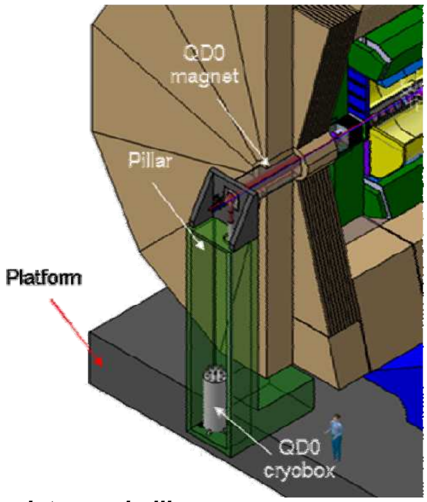


FIGURE 2.4.2.2 Details on CFRP tension plates and pillar

2.4.3. Forward Calorimeters integration

- *LumiCal :*

This precise luminosity monitor has to be well aligned with respect to the outgoing beam. It will be split in two half rings for mounting close to the beam tube. Therefore, an intermediate and tunable support is fastened at the bottom and to the support tube. Its design is the task of to the FCal collaboration [7].

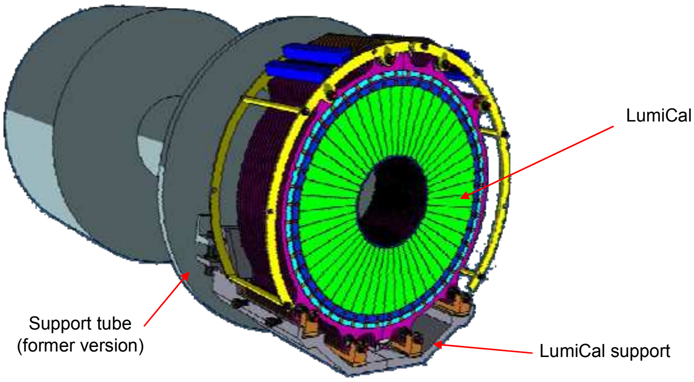


FIGURE 2.4.3.1 LumiCal and its support (still under study)

- *LHCal :*

This detector should use the same technology as the Si/W ECal. It is composed of 40 layers of 10mm thick tungsten plates. The sensitive part is made of silicon sensors. Its total weight is about 2.6 tons.

As the static loading on the tube is only vertical (weight of components), we propose to use 2 vertical plates (10mm thick in Aluminium) on each side of the LHCal to support it and take the load of the downstream components. Those plates become a structural part of the support tube assembly.

To mount it along the beam pipe, the LHcal is built in two half parts, and inserted vertically between the 2 aluminium plates (see figure 2.4.3.2)

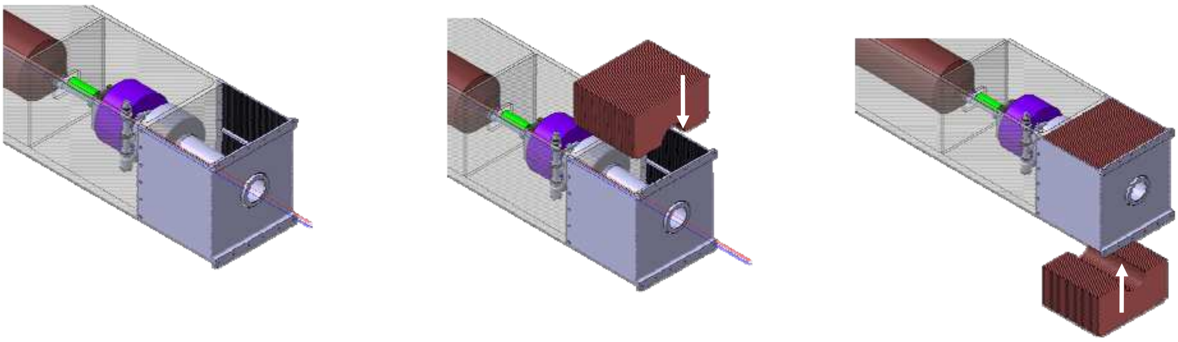


FIGURE 2.4.3.2 LHCal mounting in support tube

- *ECal ring :*

This detector fills the gap between the LumiCal and the EndCap square hole and then completes the ECal towards small polar angles. So, its technology and segmentation are similar to ECal EndCap:

- 20 tungsten layers of 2.1 mm thick
- 10 tungsten layers of 4.2 mm thick
- 3mm gap for Silicon wafers and electronic

The support consists of 2 stainless steel plates (top & bottom - 10mm thick), which are fastened to the support tube (see figure 2.4.3.3)[8].

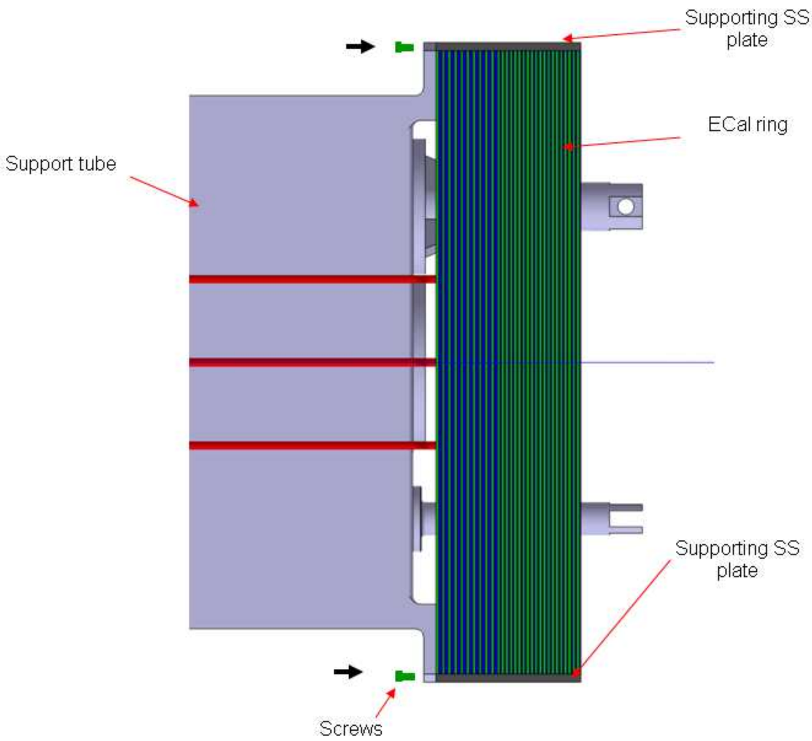


FIGURE 2.4.3.3 ECal ring mechanical design

The final configuration of the forward components is the following:

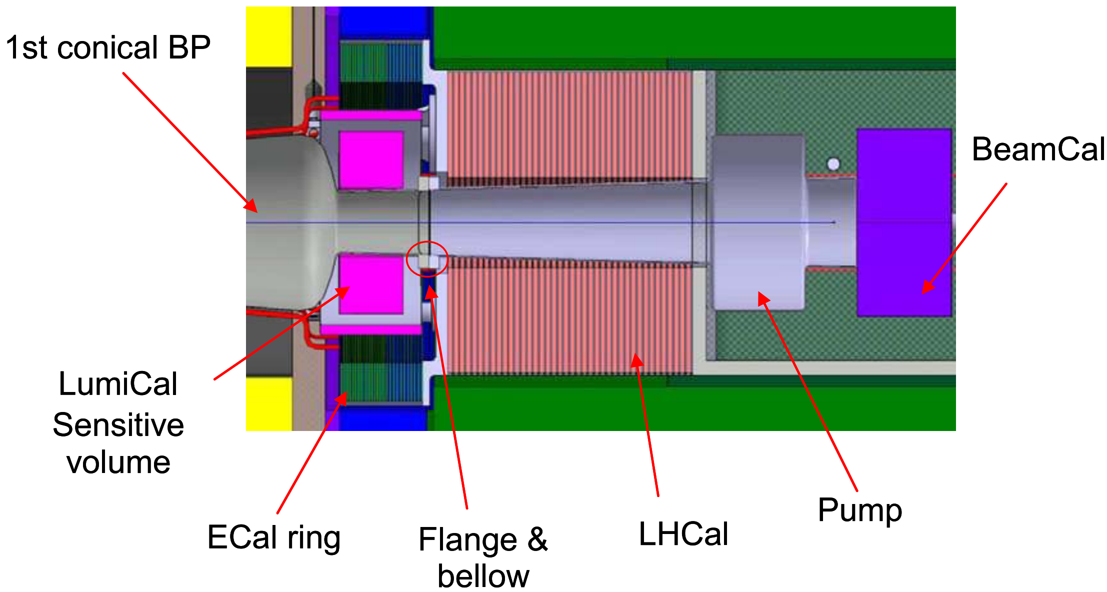


FIGURE 2.4.3.4 Vertical section of the Forward Calorimeters region

3. Cables and services

3.1. Detector cabling scheme

3.1.1. Principles

Two main constraints have driven our study:

- Allow maintenance with the minimum of cable disconnections
- Minimise the number of cables and services in the way of particles

Thus, we propose the following cabling scheme (see figure 3.1.1.1):

- Inner and forward detectors cables/services along the beam
- Barrel detectors cables/services along the coil cryostat and between central and outer rings of barrel yoke. The cable might be distributed in chimneys. This is to be studied in detail.
- Endcap detectors cables/services between barrel yoke and Endcap.

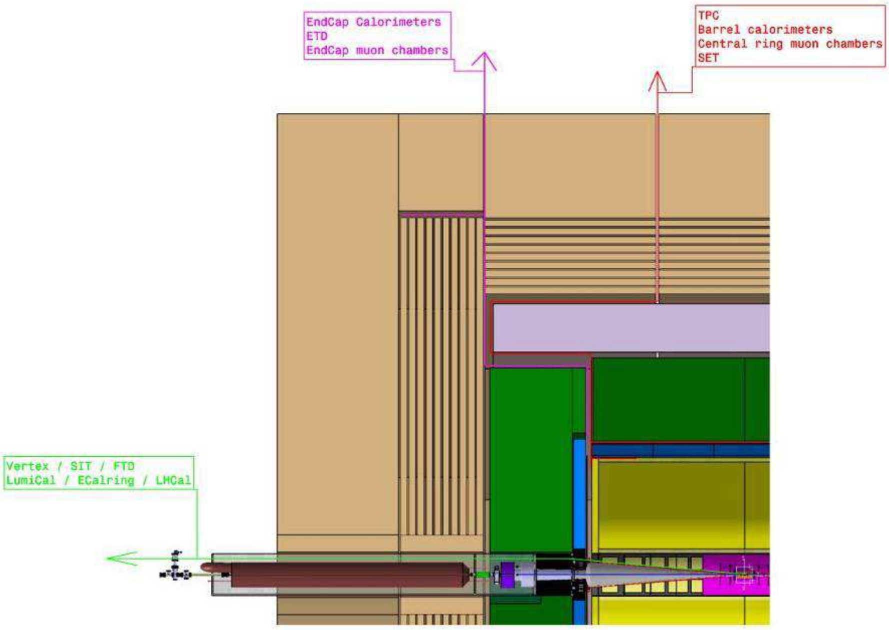


FIGURE 3.1.1.1 Cabling scheme

The inner and forward cables (in green in figure above) will be routed along the pillar and then to cable chains.

The realisation of this solution in the LumiCal region turns out to be very chellenging. The cables coming from the inner part must find their way out along the Ecalring, Lumical and support tube, but should not prevent the opening of the endcap. That last point implies a possibility of disconnection. A quick disconnection device, like a patch panel, is mandatory in this region.

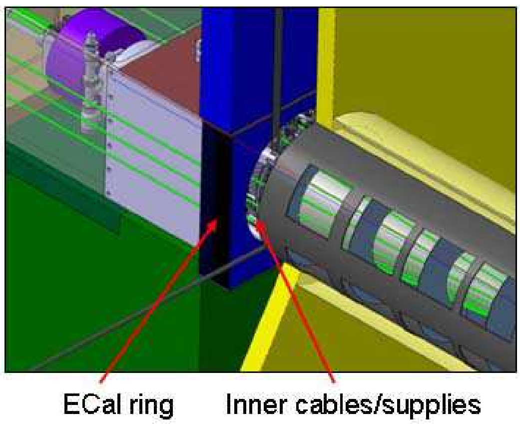


FIGURE 3.1.1.2 Forward cabling

3.1.2. Evaluation of gaps

U.Schneekloth has done an exhaustive study of the required gaps according to the cables and services volume for each sub-detectors and taking into account the mechanical tolerances for assembly or deformation[9].

	Gap (mm)
Cryostat-Yoke barrel	250
Between Barrel rings	50 mm if all around the circumference, and specifics chimneys for cryostat supply
Between Barrel and endcaps	25 mm

Table 3.1.2.1 Required gaps in ILD

The previous numbers are the minimum mechanical requirement. The final size and distribution of the gaps will also depend on the gathering of the cables, the size of their support, the needed thermal screening for cables, etc…

Another point to consider is the fact that the size of the gaps might have huge incidence on the stray field of the detector, so their shape, distribution all around the circumference or within thicker cable channels, are relevant questions and need more calculations.

Concerning the inner cables, the present design provides about 350 cm² for passing them. It's something which needs to be verified.

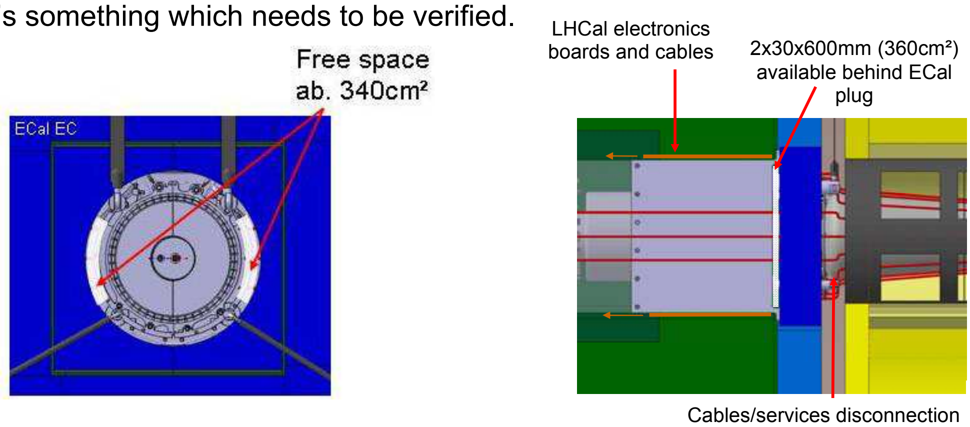


FIGURE 3.1.2.2 Gaps for inner cables

3.2. Cabling in Experimental Hall

Actually we don't have the exact details of the services for ILD, but from the CMS[10] experience we can estimate what should be the minimal environment of the detector.

3.2.1. Primary services

- Water chillers,
- High to medium voltage power transformers
- Diesel & UPS facility
- He storage & compressor plants
- Gas & compressed-air plants

Plants providing these services are usually located on surface, due to their dimensions and related risks.

3.2.2. Secondary services

- Temperature-stable cooling water for sensitive detectors
- Low Voltage/High Voltage supply for front-end electronics
- Gas mixtures for drift-chambers

- UPS power for valuable electronics
- AC-DC power converters for superconducting coil(s)
- Cryogenics & Vacuum services

They need to be close to the detector (flexible lines <50m), thus in the cavern. As those services are permanently connected to the detector, even during the push-pull, they may run into cables chains toward the detector. However some secondary services must be situated close to the detector as well, when the connection lines through the cable-chains is technically difficult or too expensive. They have to stay attached to the detector on the platform itself. But because of vibrations or electrical noise they may induced, and of the increase of the dimensions of the moving platform, they should be limited as much as possible.

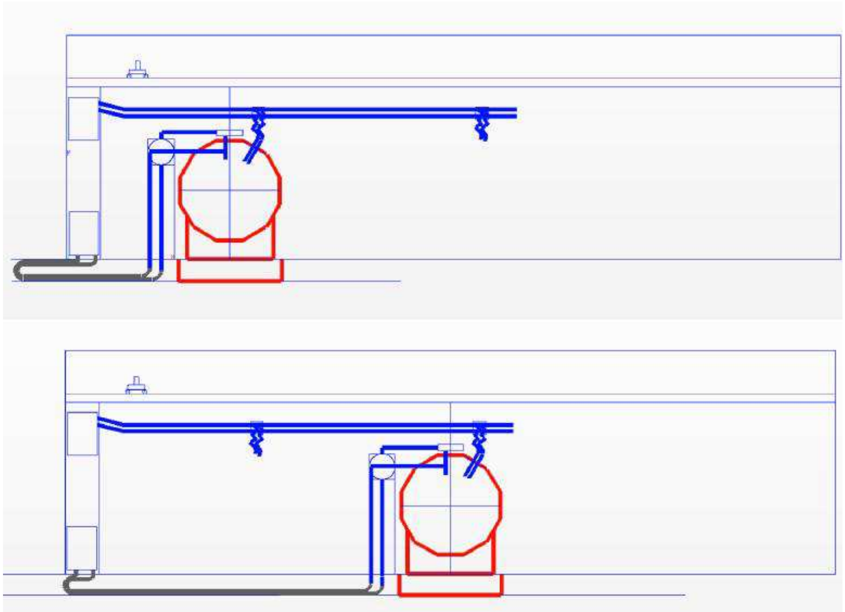


FIGURE 3.2.2.1 ILD detector in the garage position and on the beam line. The detector will be disconnected from the power bus bars (top, blue) during movement, while the cables and cryogenic service lines run in cable chains (bottom, grey).

4. Assembly and maintenance

4.1. Assembly

The strategy of assembly is strongly dependent on the site location, that means whether it will be “on surface” or underground. The last case is obviously the more delicate and that’s why in the following we will consider it and the constraints it implies.

We have to check what are the relevant parts to be assembled on surface, taking into account the weight of those elementary components thus the capacity of the gantry crane for lowering.

To ensure the quality we should perform a maximum number of tests on the sub-detectors on surface (i.e. before and after integration).

It is also to be considered that, because of a limited hall dimensions, we should minimise the number of specific tools needed underground.

4.1.1. On surface

Some parts of the detector have to be pre-assembled on surface, before lowering down in the hall as elementary pieces.

a) Endcaps

As described above, the endcaps of the yoke consist of two parts:

- The back part, in two half rings
- The front ring instrumented with the muons chambers.

On surface, this front ring should also be assembled with the FSP plate, the calorimeters endcap and the ETD. The detection components are in place and cabled.

b) Barrels

The barrel yoke is segmented in 3 rings of about 2.7 m long, equipped with muons chambers within the first half of their thickness. The central part of it will support the coil cryostat, in which the calorimeters are positioned.

c) TPC

It could be mounted on surface and cabled to be able to run some first cosmic tests on surface. It might be positioned in the calorimeters before the lowering down but this is still open.

d) All the inner parts are positioned and cabled in the ISS (Inner support structure - Beam pipes, Vertex detector, Forward tracker disks, SIT)

e) The forwards components

All the forward components have to be pre assembled and attached to the support tube (see paragraph 2.4.2 & fig.2.4.1.1).
However the Lumical and the Ecal ring have to be installed in the detector separately, because, before their mounting, the beam tube section in the forward has to be connected to the inner beam pipe.

			Weight (ton)	Total for assembly
endcaps	Yoke Back part		2370	2370
	Yoke Front ring		870	1151
		Hcal	264	
		Ecal	17	
		ETD	0.186	
Barrel	1st ring		2350	2350
	2nd ring		2350	2350
	Central ring		2350	3411
		Coil and cryostat	210+150	
		Hcal	626	
		Ecal	75	
TPC			4	4
ISS			<0.1	<0.1
Forward part			8.45	8.45

Table 4.1.1.1 Weight of ILD components

The feet of the yoke are not implemented in the calculation.
One important item which has to be checked is the possibility to have a gantry crane capacity of about 3500 tons. This could be an extra cost comparing to CMS one (2500 tons), but will give us the possibility to perform a maximum number of test on surface and save some precious time during the assembly of the detector.

4.1.2. Lowering down & integration procedure

1) The very first part to be installed in the hall, in its final position, is the 1st pillar that will sustain the support tube of the forward components
2) Then the forward part described above is fixed to that pillar, the service (vacuum and cryogenic) of the QD0 may be placed at the bottom of the pillar and connected.
3) Back part of yoke endcap is placed, split in two along the pillar
4) Front part of endcap is positioned on its support in front of the back part
5) 1st ring of Barrel yoke is lowered down
6) Then Barrel central part
7) The TPC is introduced in the calorimeters, if not installed on surface
8) Then the inner part (ISS)
9) The last ring of barrel yoke is lowered down in the Hall, and the entire barrel is gathered.
10) The same procedure as described under 1) is followed for the second endcaps part

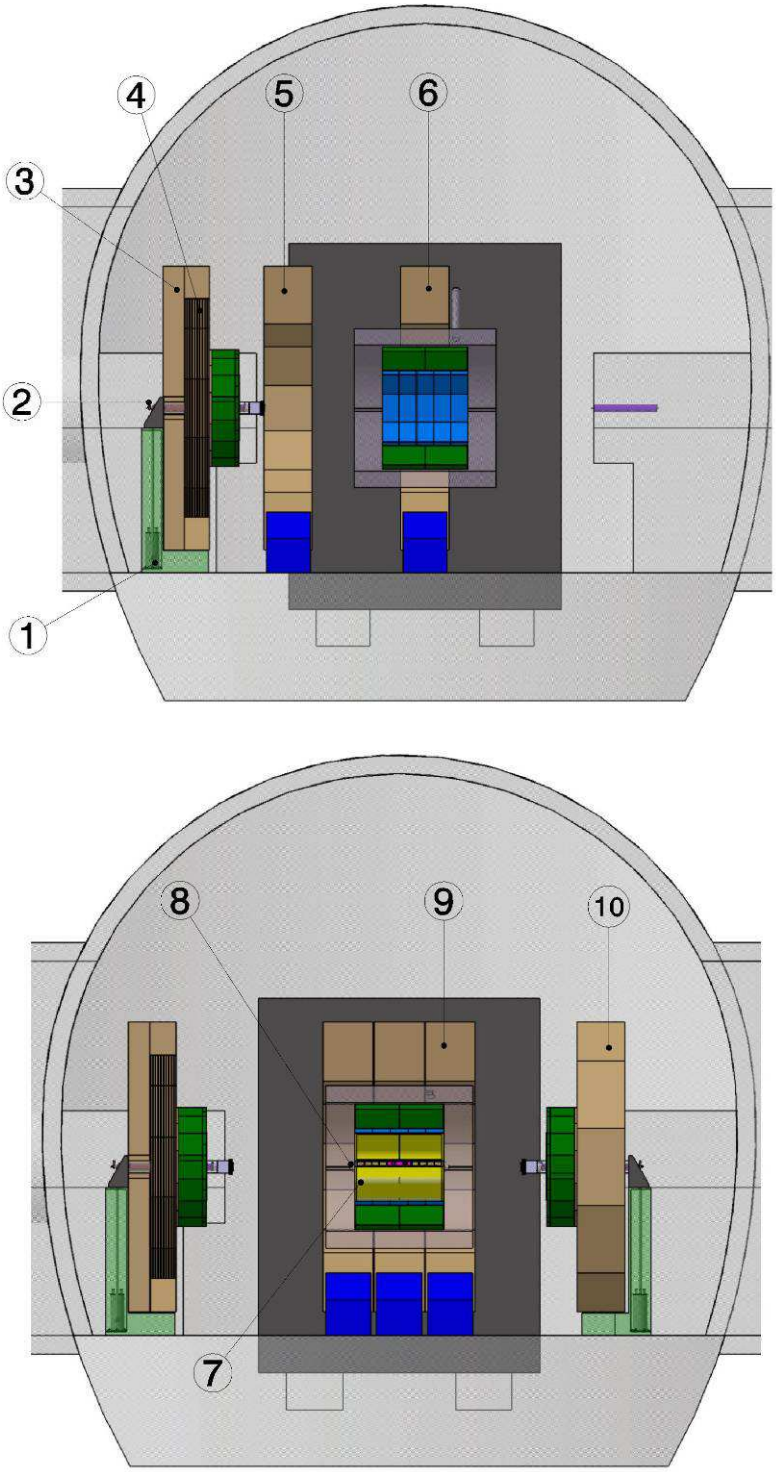


FIGURE 4.1.2.1 ILD Assembly in garage position

11) Then, the endcaps are approached to the central part
12) Connection of beam pipe (inner part) to the flange of vacuum tube (forwards), the cable of inners detectors should be pass around LHCAL
13) Positioning of the Lumical, then of the tension rods
14) Mounting of Ecal ring in two half parts

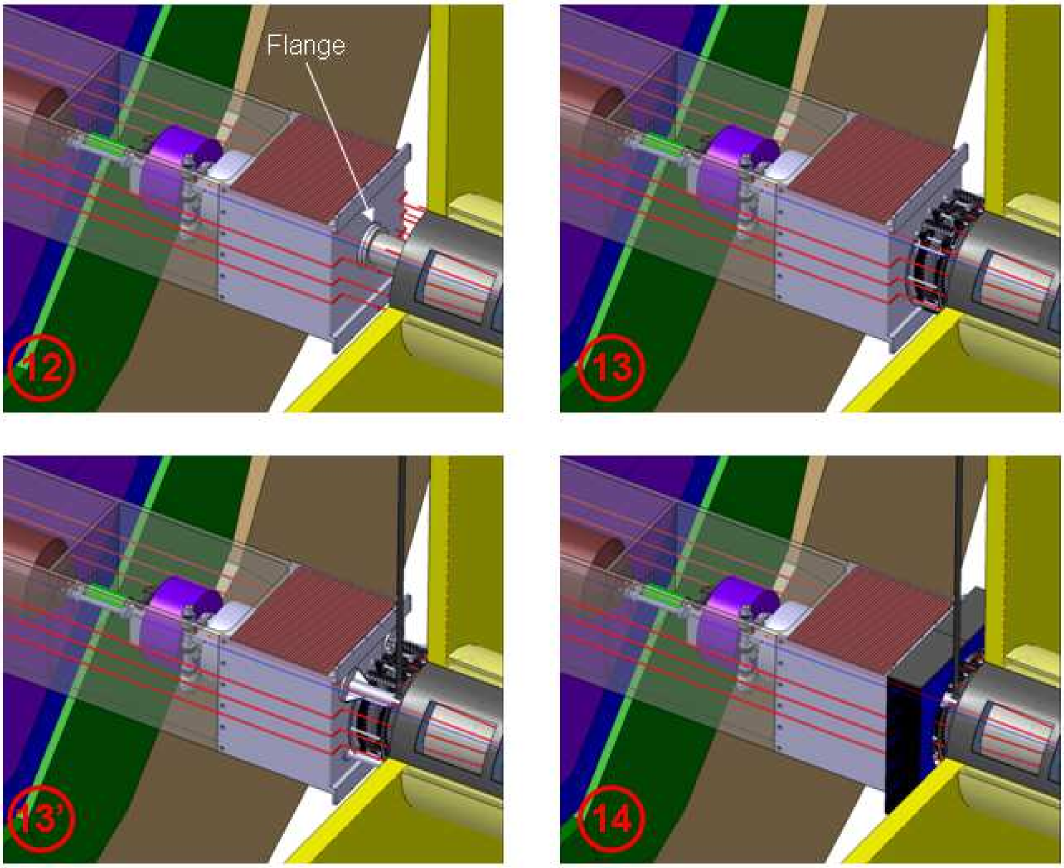


FIGURE 4.1.2.2 Mounting of the very forward area

4.2. Opening scenario & maintenance

As the ILC detectors will operate in a push-pull mode, it has been decided to only do light maintenances (few days) on beam position. Heavy maintenance which requires more days (or a month) are assumed to be performed in the garage position. That way, the running time of the machine is maximised.

4.2.1. In beam position

The opening procedure is the following (see figure 4.2.1.1):

1. Move the two back parts in x and z direction to get them close to the pillar (0 to 2)
2. Move the front ring to the pillar(3)

This gives an access clearance which is about 1,1m. It seems sufficient to reach in the detector maybe by using a special tooling, like a scaffold.

Thus, the opening of the detector allows for quick access and maintenance on:

- Forward calorimeters and components (gauges, pump, valve, etc…)
- Support tubes tension rods (adjustment is then possible)
- Inner and forward cables
- Barrel HCal electronics
- Barrel ECal cables and supplies (cooling system)
- TPC endplates
- ETD
- Endcap calorimeters' electronics
- Muon chambers' cables

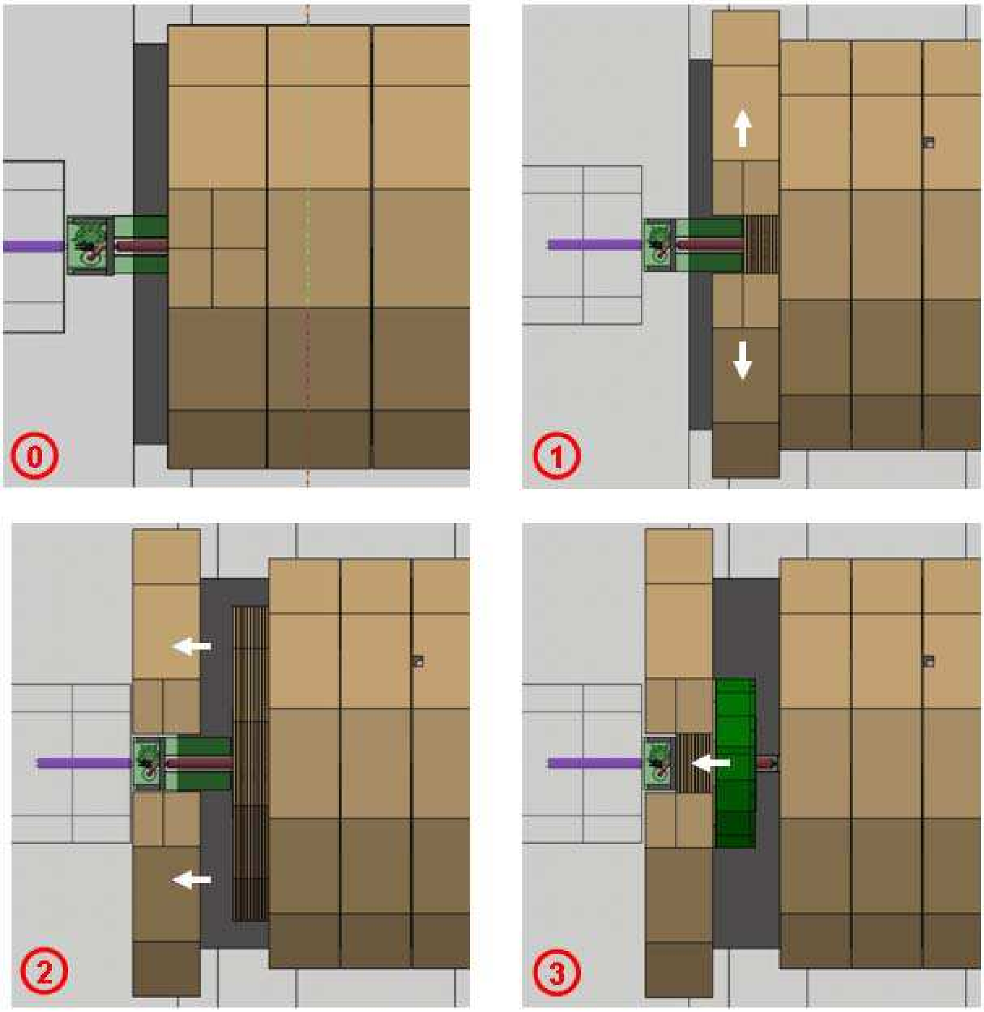


FIGURE 4.2.1.1Top view of the ILD opening scenario on beam

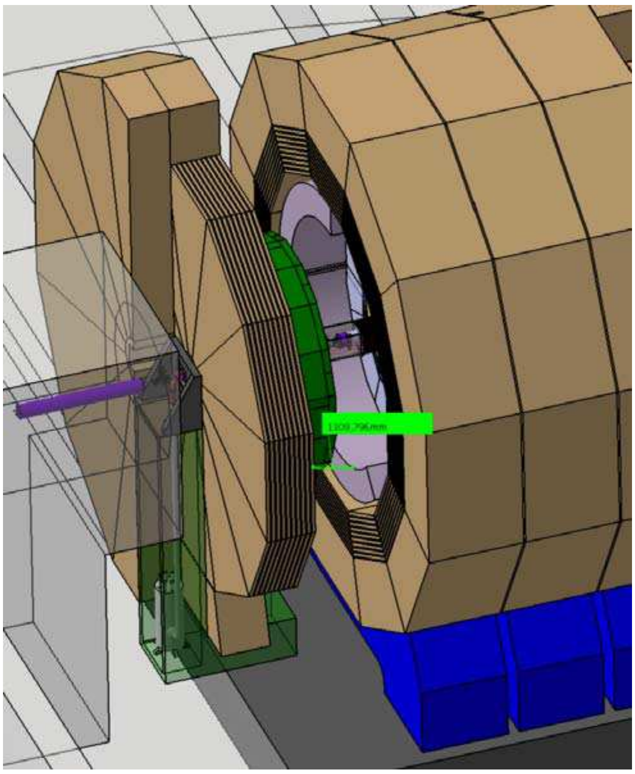


FIGURE 4.2.1.2 Access in beam position

4.2.2. In garage position

In garage position, depending on what kind of maintenance is required, both opening scenarios can be performed:

- same as on beam for light maintenance or disconnecting the beam pipe
- Reversing of the assembly sequence for important maintenance. This one provides access to every sub detectors.

Instead of moving the TPC to exchange the Vertex detector, which is impossible with the design of the forward components and also risky, we propose to achieve it by removing the ISS from the TPC and open it elsewhere. Even if it represents a important maintenance, we think it is achievable within one month.

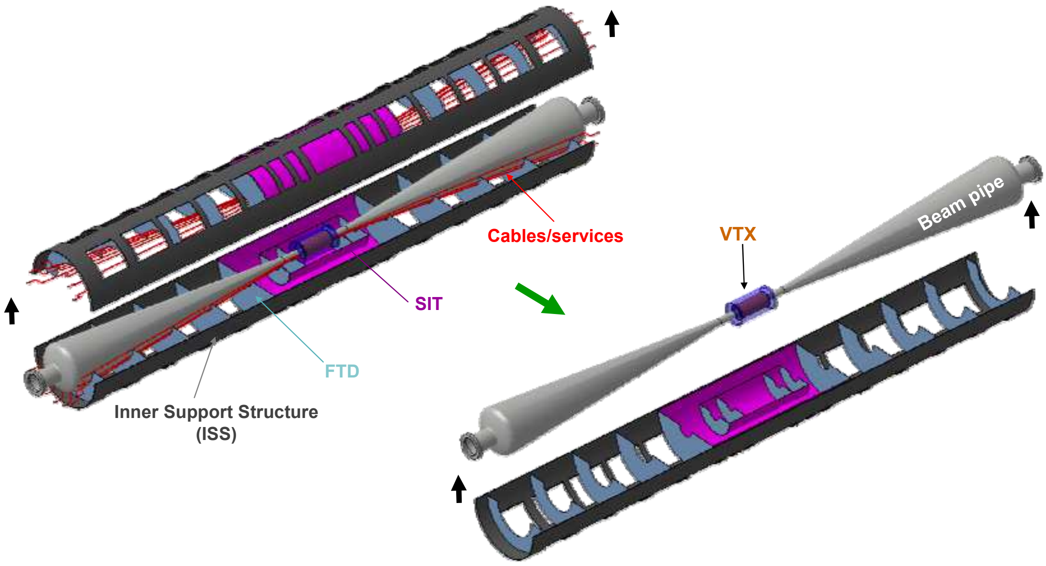


FIGURE 4.2.2.1 Maintenance scenario for Vertex detector

5. Conclusions

In this note we have described the status of the integration design in ILD detector. As said in introduction, the design is far from being finished but seems at a sufficient level of detail for the Letter of Intent step.

For the technical design phase, which represents the possible step after the LoI, a lot of studies need to be performed in every aspects of building such a detector (non exhaustive list):

- Sub-detectors integration (detailed design of each supporting method and cabling)
- Yoke design which is still evolving (splitting or not) and impact on pillar
- Push-pull system (platform design, air pads or rollers, etc…)
- Experimental hall design
- Cabling and services in the experimental hall (cables chains, cryogenic system, etc…)
- Surface assembly hall

All these issues require to create a technical management organisation once collaborations have been formed and a close discussion with both, the second detector and the BDS groups.

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